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CONTROL OF INTERMEDIATE HOST SNAILS FOR PARASITIC DISEASES – A THREAT TO BIODIVERSITY IN AFRICAN FRESHWATERS?

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ABSTRACT

We address the question of whether there is conflict between the objectives of malacologists working to control transmission of snail-borne parasitic disease in Africa, and the aim of conservationists to preserve biodiversity.

Of the approximately 330 species of indigenous gastropods known from fresh and brackish waters in Africa, about two-thirds can be classified in the IUCN Red List category of "Threatened". Most are prosobranchs (especially Thiaridae, Bithyniidae and Ampullariidae), while only 23 are pulmonates, including some species of *Biomphalaria* and *Bulinus* that are intermediate hosts for schistosome parasites. A high proportion of the threatened fauna is concentrated in three geographical areas of endemism: the lakes region of eastern Africa, the Congo (Zaire) Basin, and West Africa.

From consideration of the distribution of the snail-borne diseases schistosomiasis, paragonimiasis and fascioliasis, and the past and potential use of snail control measures against them, it is concluded that endemic snails are in most danger from molluscíding in lakes in eastern Africa. Conservation of these lacustrine mollusc faunas and the riverine fauna in the Zaire (Congo) Basin is of high importance for the preservation of biodiversity.

Fortunately, the risk from mollusciciding has diminished due its high cost and the switch from area-wide to focal application. Possibly greater threats to biodiversity than snail control are pollution, hydrological engineering and degradation of habitat.

High biodiversity is a sign of the ecological health of an aquatic habitat. It is in the interests of medical malacologists and health workers, as well as conservationists, to do all they can to preserve biodiversity. Environmentally damaging dams and irrigation schemes can cause serious health problems as well as damaging natural ecosystems, while pollution and habitat degradation threaten water supplies as well as species.

There is good reason for conservation issues to be taken into account when snail control operations are planned. Medical malacologists can contribute to preserving biodiversity by minimising the use of molluscicide, by working with a knowledge of snails that should be protected, and planning operations in consultation with conservationists.

Keywords: Africa, biodiversity, conservation, fresh water, Mollusca, schistosomiasis, snail-borne disease, snail control

INTRODUCTION

For several decades, the means of controlling snail-borne parasitic diseases of humans and domestic livestock in Africa have included control of the intermediate host. This has been attempted mainly through the use of molluscicides, by environmental modification, and by the use of biological control agents.

The molluscan fauna of fresh water in Africa includes a high proportion of endemic species, of which many are known from only very small areas and are believed to be vulnerable to extinction (Baillie & Groombridge, 1996; Brown & Kristensen, 1998). The conservation of these organisms is desirable as part of the overall strategy to preserve the world's biodiversity. The occurrence of vulnerable species of snail is patchy, because to a great extent the endemic species are clustered in association with certain lakes and river systems. Some of the regions with snail faunas of high conservation value are also areas of snail-borne parasitic diseases of humans, while others are not. Controlling the intermediate hosts of schistosomiasis could bring medical malacologists into conflict with conservationists working to preserve biodiversity (Brown & Kristensen, 1998).

Snail control by chemical means has un-

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specific results, causing death of non-target organisms, including fish, amphibia and insects as well as harmless snails. Such indiscriminate killing is rightly regarded with concern by local people as well as professional conservationists. In such artificial habitats as reservoirs and irrigation systems, non-specific molluscicides may do little damage, since the snail faunas are usually low in diversity and composed of widely distributed species. But in rivers and lakes, snail control could do catastrophic harm to endemic snail faunas.

In a world with ever growing awareness of the importance of conserving biodiversity, snail control activities have to be questioned, and medical malacologists should take conservation issues seriously. By striving to minimise the damage done by snail control to non-target organisms, medical malacologists can play an active part in protecting the biodiversity on our planet.

This present paper summarises the conservation status of the freshwater snail fauna of the African continent, and assesses the degree of threat posed by measures to control the intermediate hosts for the major snail-borne parasitic diseases of humans and domestic livestock. Attention is drawn to the mutual interest of medical malacologists, health authorities and conservationists in working cooperatively. We also recommend practical ways in which medical malacologists can contribute to conservation.

SNAIL-BORNE PARASITIC DISEASES IN AFRICA

Schistosomiasis or bilharzia is by far the most important of the snail-borne diseases of humans in Africa. Over a period of several decades, snail control by molluscicides has played a part in controlling the disease, in limited areas and with widely varying success. Two species of *Schistosoma* are responsible for most cases of schistosomiasis in humans, *S. haematobium* causing the urinary form of the disease and *S. mansoni* the intestinal form. Their intermediate hosts belong, respectively, to the pulmonate genera *Bulinus* and *Biomphalaria*. Both these forms of schistosomiasis are transmitted in large areas of Africa (Fig. 1), parts of which have highly diverse faunas of aquatic snails that are of high priority for conservation and merit protection from snail control operations.

Paragonimiasis, the lung-fluke infection of humans, is reported from a comparatively small area of western Africa (Fig. 1), extending from Gambia to Zaire, and is found most commonly in Liberia, Nigeria and Cameroon (Brown, 1994). Apparently two species of *Paragonimus* are involved. Their metacercariae are found in freshwater crabs, which serve as the second intermediate host, but the identity of the molluscan first intermediate host is still not known with certainty. It probably is one or more of the species of *Potadoma* (Thiaridae) that occur in forest streams within the areas of disease transmission. No attempt has been made, to our knowledge, to control transmission of paragonimiasis by measures aimed against the first intermediate host. Any snail control activities that might be planned should take into account that the streams and rivers of West Africa are also inhabited by rare endemic prosobranch species (Brown & Kristensen, 1993; Brown, 1994).

Bovine schistosomiasis caused by *Schistosoma bovis, S. curassoni* and *S. mattheei* is common in cattle in Africa and severe infection can cause mortality and considerable economic loss. The intermediate hosts in most of Africa are species of *Bulinus,* while *Planorbarius* is possibly a host for *S. bovis* in northwest Africa. Snail control appears to have been used on only a small scale, as in a reservoir and associated drinking trough (Van Wyk et al., 1974: 46–47).

Paramphistomiasis is an infection of domestic livestock and wild grazing animals in Africa, caused by a variety of species of Paramphistomatidae and related trematode families, which can be of veterinary importance locally. Most of the recorded intermediate hosts are species of *Bulinus,* and some species of parasite develop in *Biomphalaria, Ceratophallus* and *Lymnaea* (Brown, 1994). As for bovine schistosomiasis, it appears that any snail control against paramphistomiasis has been only local. The development of acute infection in livestock depends on exceptional conditions, which lead to a dense population of infected snails in a limited site (Dinnik, 1964; 452). According to Dinnik, this takes at least two months, allowing time for the potential danger to be recognised and a decision to be taken on whether to apply molluscicide or to exclude livestock from the site.

Fascioliasis, or liver-fluke infection, is widespread in cattle and sheep in Africa, but human infection is rare in the tropical region

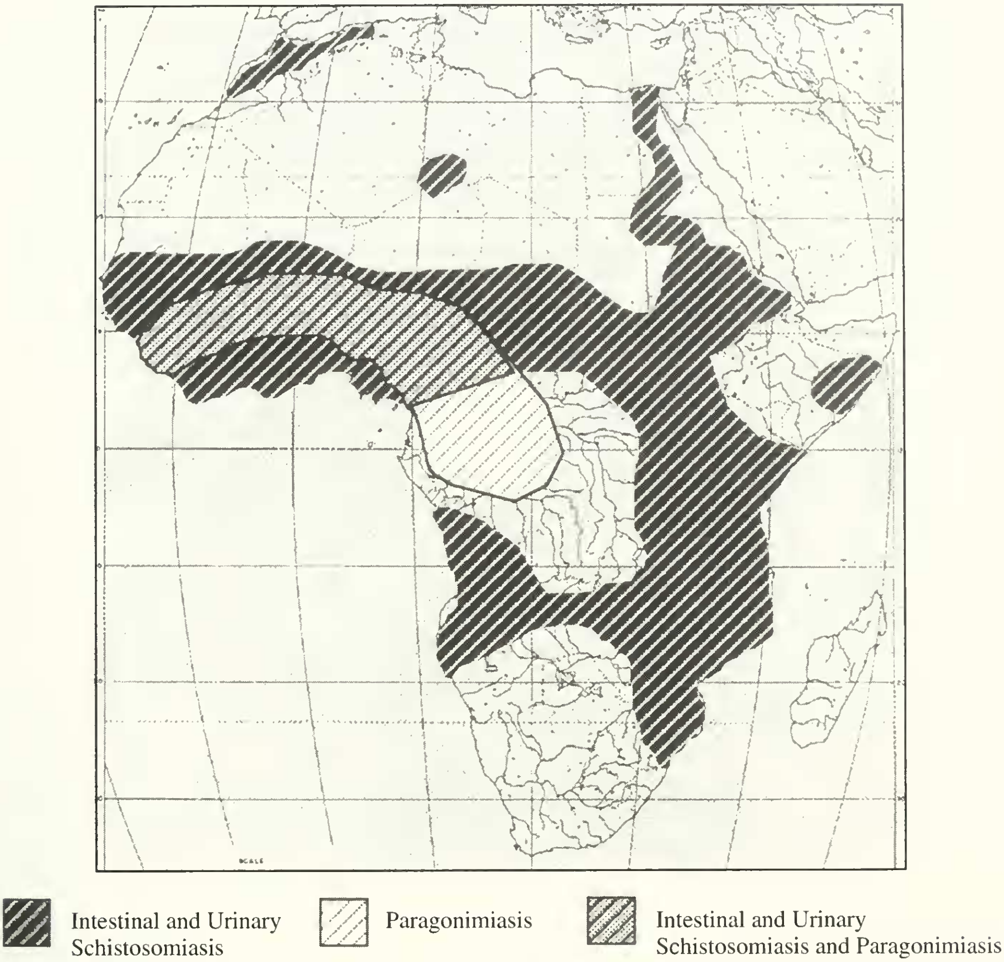

FIG. 1. Distribution of intestinal and urinary schistosomiasis, and paragonimiasis in Africa.

(World Health Organisation, 1990). Both *Fasciolia gigantica* and *F. hepatica* are reported, the former widely distributed, the latter apparently restricted to highland areas in eastern and southern Africa. This pattern may reflect the preference of *F. hepatica* for the snail host *Lymnaea truncatula,* which is restricted to cool highland areas, whereas *F. gigantica* develops in *L. natalensis,* a snail found throughout tropical and subtropical Africa (Brown, 1994). Infection of domestic livestock can cause considerable economic loss, and trials to control the snail host with molluscicide have been carried out in Kenya (Preston & Castelino, 1977) and Lesotho (Prinsloo & Van Eeden, 1977).

THREATENED FRESHWATER SNAILS IN AFRICA

Assessing the Threat

World wide efforts to save species from extinction are focused in the International Union for Conservation of Nature and Natural Resources (IUCN). For nearly 30 years, IUCN has published Red Data Books and Red Lists of species threatened by severe reduction in population and possible extinction. Information is collected by the Species Survival Commission of IUCN with the help of expert groups, one of which is the Mollusc Specialist Group. Many species of African freshwater snails are included in the most recent IUCN Red List of Threatened Animals (Baillie & Groombridge, 1996). Each species is classified in one of a number of categories according to its degree of rarity and a judgement of its vulnerability to extinction. The category for a mollusc is decided usually according to the number of localities where it has been found and the total area of its distribution. The system of classification is explained in detail in IUCN (1994) and discussed by Seddon (1998). At one end of the scale, an abundant and widely distributed species, such as *Biomphalaria pfeifferi,* would be classified as "Of Least Concern". At the other extreme, a species found in only a single locality or in a small area qualifies for inclusion in the Critically Endangered (CR). High conservation status is given to all species that occur in a single lake, no matter how large, because an incident of severe pollution could have a devastating effect on the fauna of even so big a waterbody as Lake Tanganyika.

Taxonomic Composition of the Threatened Snails

The total number of snail species in fresh and brackish water on the African continent is estimated at 400 (Brown, 1994). Uncertainty stems largely from ignorance of the exact number of species of endemic prosobranchs in Lake Tanganyika, of Hydrobiidae in North West Africa, and of the ancylid genera *Burnupia* and *Ferrissia* throughout their African ranges. Of the 332 indigenous species listed by Brown (1994: 29–34), 207 are considered threatened – 184 prosobranchs and 23 pulmonates (Table 1).

TABLE 1. Taxonomic composition of the snail fauna of fresh and brackish waters in Africa considered to be threatened (based on checklist in Brown, 1994: 29–34; IUCN Red List, 1996; Brown, 1994, and unpublished data). Notes: (1) A threatened species is one classified, or likely to be so classified, in one of the IUCN categories Critically Endangered (CR), Endangered (EN) or Vulnerable (VU); (2) Introduced species are excluded; (3) Hydrobiidae here include only the species found in tropical Africa; (4) In the Ancylidae the species of *Burnupia* and *Ferrissia* are each treated as a single aggregate.

Family	No. of Species	No. Threatened
Prosobranch		
Neritidae	17	1
Viviparidae	19	17
Ampullariidae	27	13
Valvatidae	1	0
Hydrobiidae	13	12
Pomatiopsidae	10	10
Bithyniidae	35	31
Assimineidae	11	10
Thiaridae	109	90
Melanopsidae	1	0
Potamididae	4	0
Subtotal	247	184
Pulmonata		
Ellobiidae	7	1
Lymnaeidae	5	0
Ancylidae	5	1
Planorbidae	68	21
Subtotal	85	23
Total number of species	332	207

Among prosobranch families, the Thiaridae has the largest number of threatened species by far, due to the presence of endemic species in lakes Malawi and Tanganyika, and the restricted occurrence in western and central Africa of many species of *Cleopatra, Melanoides* and *Potadoma,* which live in rivers and streams.

Six other prosobranch families include high proportions of threatened species, as follows. Bithyniidae – 31 threatened species, including about 20 *Gabbiella* found in Equatorial Africa in varied habitats from seasonal pools to large lakes, four *Sierraia* and one *Soapitia* known only from rivers in West Africa, three monotypic genera confined to the lower Congo River Basin (*Congodoma, Funduella* and *Liminitesta*) and two genera restricted to north east Africa (*Incertihydrobia* and *Jubaia*).

Viviparidae – 17 threatened species of *Bellamya* and *Neothauma,* mostly confined to large lakes.

Ampullariidae – 13 threatened species, comprising a *Pila,* 10 *Lanistes* found in Equatorial Africa in lakes rivers and streams, and the monotypic genera *Afropomus* and *Saulea* known only from small areas in West Africa.

Hydrobiidae – 12 threatened species in tropical Africa, comprising nine species of uncertain generic position, found in restricted localities scattered along the western coast and classified in *Hydrobia* and *Potamopyrgus,* and

TABLE 2. The species of *Biomphalaria* and *Bulinus* classified as Threatened or Near Threatened (category LR nt) in 1996 IUCN Red List (Baillie & Groombridge, 1996)

	Threatened	Near threatened	Distribution
Biomphalaria angulosa		x	Tanzania, Zambia, Malawi
B. barthi	x		Eastern Ethiopia
B. salinarum		x	Angola
B. tchadiensis	x		Lake Chad
*B. smithi**	x		Lake Edward and Marambi Crater lake
*Bulinus hightoni**	x		NE Kenya
*Bul. obtusus**	x		Chad
Bul. hexaploidus		x	Ethiopian highland
Bul. nyassanus	x		Lake Malawi
Bul. octoploidus		x	Ethiopian Highland
Bul. succinoides	x		Lake Malwi
Bul. transversalis	x		Lake Victoria
*Bul. trigonus**	x		Lake Victoria
Bul. barthi		x	Kenya, Tanzania
Bul. browni		x	Kenya
Bul. camerunensis	x		Cameroun, crater lake
Bul. canescens		x	Angola, Zambia
Bul. crystallinus		x	Angola, Gabon

*Not yet included in an IUCN List, but suitable for the vulnerable (vu) category.

three *Lobogenes* confined almost entirely to south east Congo (Democratic Republic). In this family, the total number of species and the number threatened will rise considerably when the fauna of North West Africa is better known.

Pomatiopsidae – 10 threatened species of *Tomichia*, seven found in restricted localities near the southern coast and three in central Africa.

Assimineidae – 10 threatened species, comprising an *Assiminea* from each of the east and west coasts, four *Eussoia* from eastern Africa and four species from the lower Congo River, below Kinshasa (*Pseudogibbula, Septariellina* and *Valvatorbis*).

Almost all the 23 threatened pulmonates belong to the Planorbidae (Table 1). The genera contributing most species are *Ceratophallus* with eight confined to lakes in eastern Africa, and *Biomphalaria* and *Bulinus* with a total of 10 (Table 2). *Biomphalaria barthi* is known only from two shell deposits in eastern Ethiopia and may be extinct, while *B. tchadiensis* is perhaps merely a conspecific form of *B. pfeifferi,* but taking into account also the eight species classifiable as "Near Threatened" (Table 2) it is clear that *Biomphalaria* and *Bulinus* are of interest to conservationists as well as medical malacologists.

Conservation status of *Biomphalaria* and *Bulinus*

Although none of the major intermediate hosts for schistosomes appears in Table 2, this list does include four species reported to be involved in transmission locally. *Biomphalaria angulosa* has been observed to transmit *S. mansoni* on the shore of Lake Malawi (Teesdale, 1982). *Biomphalaria smithi* is known only from Lake Edward and the nearby Mirambi crater lake in Uganda; it proved susceptible to infection with *S. mansoni* in the laboratory (Cridland, 1957) and therefore is likely to be an intermediate host in nature. *Bulinus camerunensis* is the intermediate host in a well-known focus of *S. haematobium* at Barombi Kotto crater lake in Cameroon (Duke & Moore, 1976). *Biomphalaria crystallinus* was implicated by Jelnes & Highton (1984) in transmission of *S. intercalatum* in Gabon.

It is their restricted distributions that give conservation interest to the snails listed in Table 2. *Bulinus camerunensis* is found in only one other lake besides Barombi Kotto, while others are each restricted to a single lake (*Biomphalaria tchadiensis, Bulinus nyassanus, B. succinoides, B. transversalis* and *B. trigonus*). The others are found in more small waterbodies, but from only small geographical areas.

REGIONAL ENDEMIC SNAIL FAUNAS AND THE DISTRIBUTION OF SNAIL-BORNE DISEASE

The important contribution of lakes and rivers to the diversity of freshwater snails in Africa is seen when we consider the geographical distribution of the threatened species. Nearly 70% of them are concentrated within three geographical areas (Table 3), and they live mostly in rivers of West and central Africa and the lakes in the eastern rift valleys. The Congo River and lakes Tanganyika and Malawi each have an outstandingly rich assemblage of unique prosobranchs that deserve careful monitoring to ensure their protection.

These areas will be considered in more detail, after three other areas each with smaller numbers of threatened species.

Northwest Africa (Fig. 2)–The freshwater molluscs are mostly of palaearctic origin. This fauna is well described apart from the Hydrobiidae, which are represented by several genera, of which probably many species have yet to be described (Boeters, 1976; Kristensen, 1985; Ghamizi et al., 1999). The distribution of each species is apparently very limited, and many live in subterranean groundwaters and wells in the Mahgreb area of Morocco. Such habitats appear to be comparatively safe from operations to control *Bulinus truncatus,* the intermediate host for *S. haematobium,* which is widespread in northwest Africa. Yet it is important to be alert to the damage that could be done to this unique hydrobiid fauna by molluscicides seeping into ground waters.

Nile Basin, in Egypt and Sudan, and the upper Blue Nile catchment in Ethiopia (Fig. 2)–Within this basin are a wide variety of aquatic habitats, including the large lakes Albert and Victoria that are dealt with below in the section on East African lakes. The other areas considered here are for snails found in nonlacustrine waterbodies. In Egypt and Sudan, the comparatively few endemic species (Brown, 1994: table 12.16) are *Theodoxus niloticus, Valvata nilotica, Gabbiella schweinfurthi, Gyraulus ehrenbergi* and *Biomphalaria alexandrina.* This region is a major area of transmission for both *S. haematobium* and *S. mansoni.* As molluscicide has been ap-

TABLE 3. The geographical areas of Africa that support the major concentrations of threatened species of freshwater snails.

Area	No. Threatened Species
West Africa: Cameroun and westwards into Sierra Leone	29
Congo Basin and Lualaba river systems	40
Large lakes: Albert, Malawi, Tanganyika, Victoria and Mweru	72
Total	141 (69% of the total threatened species)

plied intensively for decades in irrigated areas, and there has been much human activity along the lower Nile for many centuries, it might be expected that some endemic molluscs have already been eliminated. No evidence can be seen for this, however, in deposits of shells of Neolithic age (Gardner, 1932) that are, apart from changes in nomenclature, no different from species still living in modern Egypt (Brown, 1994: 505). The most vulnerable of the endemic snails seem to be *Gabbiella schweinfurthi,* found in only a few localities fringing the Sudd swamp, and *Gyraulus ehrenbergi* known from a few canals and drains in the Delta Region of Egypt. It may be that snails indigenous to the lower Nile will suffer through competition from the introduced *Biomphalaria glabrata,* recently established in irrigation and drainage systems (Yousif et al., 1996).

The upper catchment of the Blue Nile in the Ethiopian highlands includes Lake Tana, which surprisingly seems to lack any endemic snails, as does the Blue Nile itself. In small tributary streams, however, live *Ancylus regularis, Bulinus hexaploidus* and *B. octoploidus,* all classified as Near Threatened (Baillie & Groombridge, 1996) because of their restricted distributions. *Schistosoma haematobium* is not known from this region, and although transmission of *S. mansoni* is widespread it is absent from above about 2200 m altitude. Fascioliasis is widespread in sheep (Goll & Scott, 1979). We have seen no report of snail control being used to restrict transmission of either liver-fluke or schistosomiasis. Widespread use of molluscicides would be cause for concern, as streams inhabited by *B.*

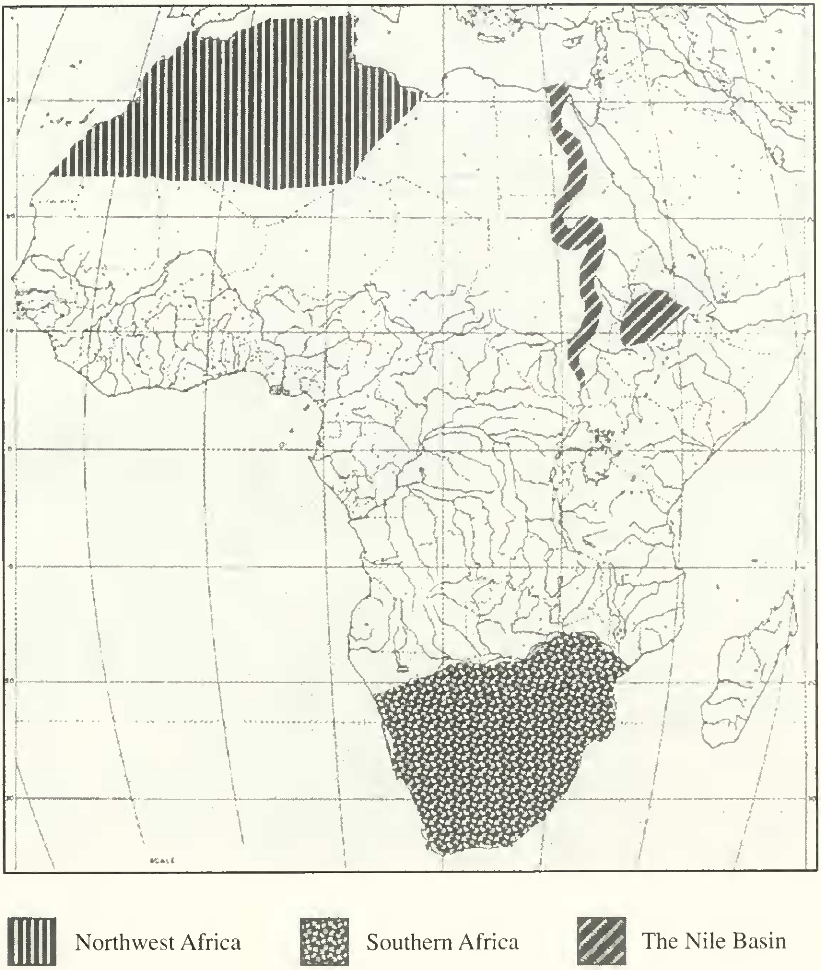

FIG. 2. Some areas of Africa with endemic snail faunas: Northwest Africa, Southern Africa, Nile Basin in Egypt and Sudan, and upper catchment of Blue Nile.

hexaploidus and *B. octoploidus* flow through the grazing pastures and close to villages.

Southern Africa (Fig. 2) – South of the Zambezi River endemic species are comparatively few, but of high conservation importance are the species of *Tomichia* (Pomatiopsidae) living in lagoons, streams and springs near the coast in the Republic of South Africa. All but one of these species occur in a climatic region too cool for transmission of schistosomiasis, and the main threat to their survival is destruction of habitat. Only *T. natalensis* occurs in the tropical region of South Africa, in a small area of the coastal plain of Zululand. Here it is vulnerable to operations to control *Bulinus globosus,* the intermediate host for *S. haematobium* locally, though the main threat is probably sugar-cane cultivation.

Fascioliasis of domestic livestock is of sufficient economic importance in Lesotho for attempts to have been made to control the intermediate host *Lymnaea truncatula* by use of molluscicide. Fortunately, no snail species is known to be endemic to Lesotho and the whole snail fauna is poor, reflecting the high altitude and cool climate.

West Africa (Table 3, Fig. 3) – Most of the 29 threatened species are prosobranchs living in streams and rivers in highland forested areas. *Bulinus camerunensis* is known only

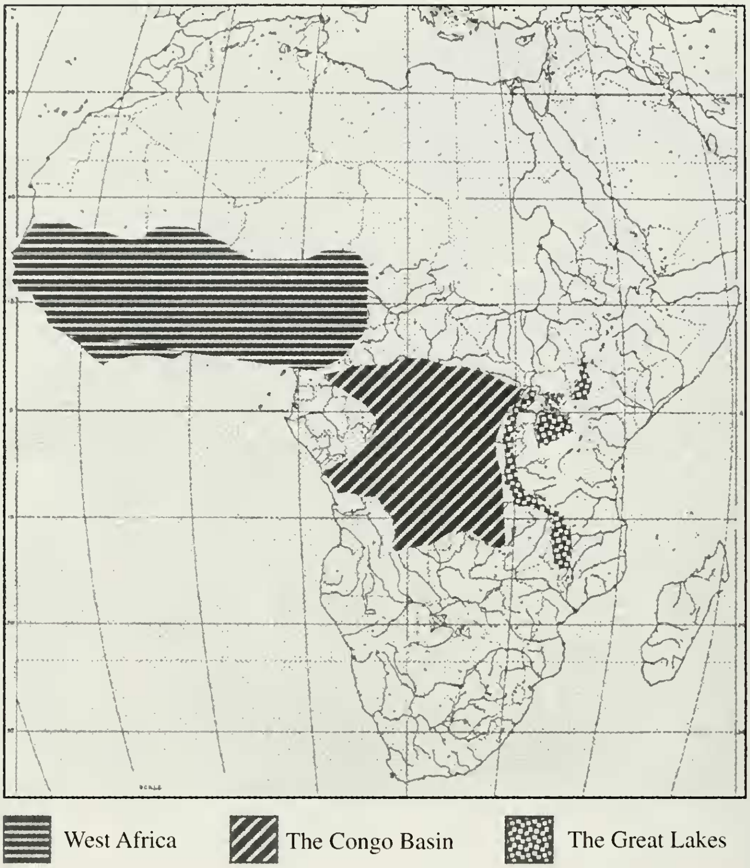

FIG. 3. Some areas of Africa with endemic snail faunas: West Africa, Congo Basin, East African lakes.

from two crater lakes in western Cameroon. Although both urinary and intestinal schistosomiasis are widespread in West Africa, the habitats of the endemic prosobranchs do not usually lie within the major areas of infection. Snail control by molluscicides in and near Lake Volta has probably not harmed the rare prosobranchs found only in the Volta Basin, as these (*Pseudocleopatra*) are known only from streams at higher altitude in the hills above the eastern side of the lake. A greater risk to threatened species in West Africa seems to lie in any attempt to reduce transmission of paragonimiasis through snail control, since this disease unlike schistosomiasis is associated with streams in highland forested areas.

Congo Basin (Fig. 3, Table 3)—Here occurs a major endemic snail fauna comparable in conservation importance to that of the Rift Valley lakes. About half of the 100 or so species known are endemic (Brown, 1994: tables 12.14, 12.15). Of about 40 species believed to be threatened, few occur in standing waterbodies (e.g., *Gabbiella matadina* known only from a reservoir), and the majority are confined to the Congo/Lualaba river system. The riverine species can be divided into three groups: those in headwater streams (*Lobogenes, Potadoma*), those in the slower-flowing parts of rivers in the upper and middle basin (*Melanoides*, *Potadomoides*), and rheophilous species in rapidly flowing stretches of the lower Congo River (*Congodoma, Hydrobia, Liminitesta, Pseudocleopatra, Pseudogibbula, Septariellina, and Valvatorbis*).

Schistosomiasis is widespread in the Congo Basin, but most transmission takes place in small waterbodies rather than major rivers, which do not generally provide favourable habitats for pulmonates. Usually the volume of water carried by the rivers is so large that the small amounts of molluscicide that might be received by drainage from treated sites near the river banks may cause little harm. However, extreme caution should be excercised in any application of molluscicide in the lower Zaire region, especially near Matadi where rocky rapids are the habitat for specialised rheophilous prosobranchs, including assimineids with remarkably modified shells (*Septariellina* and *Valvatorbis*).

East African lakes (Fig. 3, Table 3) — Lakes in the rift valleys of eastern Africa support the largest group of endemic and threatened snails. Lakes Albert, Malawi, Mweru, Tanganyika and Victoria have about 87 endemic species (Brown, 1994; tables 12.6, 12.7, 12.8, 12.10, 12.11). Of about 70 classified as threatened, the biggest group is the more than 30 "thalassoid" prosobranchs of Lake Tanganyika. Also of high priority for conservation are the species of *Bellamya, Lanistes* and *Melanoides* endemic to Lake Malawi. The other lakes have varying numbers of endemic *Bellamya, Gabbiella, Melanoides* and *Cleopatra*. Endemic pulmonates are few, two species of *Bulinus* in each of lakes Malawi and Victoria and four species of *Ceratophallus* endemic to Lake Victoria. There may also be endemic lacustrine species of the ancylids *Burnupia* and *Ferrissia,* but their validity needs confirmation.

These lakes lie within transmission areas for both urinary and intestinal schistosomiasis, and transmission sites of particular importance are known on or near the shores of lakes Malawi, Tanganyika and Victoria. Transmission of schistosomiasis has long been known in scattered marshy sites around Lake Malawi, but recently the incidence of urinary schistosomiasis has increased, possibly due to overfishing of the molluscivorous fish population and a resulting increase in the intermediate host *Bulinus globosus* (Msukwa & Ribbink, 1998, and references therein). People are apparently now acquiring infection on open shores, where endemic prosobranchs are found, as well as in marshy sites. At Lake Tanganyika there are important foci of schistosomiasis at Bujumbura and Kalieme, and the disease is widespread on the Ruzizi plains (Gryseels & Nkulikyinka, 1988). Increasing human population and developments in agriculture, industry and tourism around these lakes may lead to demand for more effective control of schistosomiasis. The risk of damage to the endemic snail faunas makes the use of molluscicide highly undesirable.

The rich endemic snail faunas in lakes and rivers contrast strongly with the poor assemblages of species found in artificial waterbodies such as dams and irrigation systems. In an irrigated area of the Niger Basin in Mali, only 13 species out of about 70 known from the West African region were found (Madsen et. al., 1987), all of them widely distributed. In the Blue Nile Irrigation Project area in Sudan, only 11 species were recorded (Madsen et al., 1988).

THREATS TO THE FRESHWATER SNAIL FAUNA

Snail control is one of many threats to freshwater snails in Africa. Before assessing the danger from snail control we consider briefly some effects of environmental change (pollution, destruction of habitat) and the increasing possibility of competition from invasive species.

Environmental Changes

Besides sewage effluent, which the invasive *Physa acuta* tolerates remarkably well (Brown, 1994: 408, 431), African fresh waters are contaminated by industrial waste and agricultural chemicals (herbicides and pesticides), while the prospect of oil production poses further danger. Pollution in Lake Tanganyika already causes concern and extensive petroleum exploration has been conducted near the lake (Cohen, 1991). There is an urgent need for data to assess the impact of pollution on the ecosystem of Lake Tanganyika and other African fresh waters.

Destruction of habitat results from hydrological engineering, dam-building, construction of irrigation schemes, drainage and water extraction. Extensive parts of river basins have been submerged by large dams (e.g., Aswan, Kainji, Kariba and Volta), while large areas of flood plain and natural wetland have been replaced by major irrigation schemes (e.g., Gezira in Sudan, Office de Niger in Mali and South Chad in Nigeria). Such developments are not known to have caused the extinction of any species of aquatic mollusc, but they may reduce biodiversity locally, since in general dams and irrigation channels are colonised by a small number of molluscan species, of which a few may establish large populations. Fortunately, the Congo River system appears to be little affected by dam-building. It cannot be too strongly urged that any plans for hydrological interventions in this basin should take into account the value of the endemic snail fauna.

A general threat to the habitats of molluscs in both rivers and lakes, and one of the most difficult to mitigate, is the high load of suspended sediment carried by inflowing streams, due to deforestation in the surrounding catchments.

Invasive Snails

African indigenous freshwater snails face competition from introduced species (Brown, 1994; Appleton & Brackenbury, 1998), of which some have become invasive and established extensive distributions (*Physa acuta* and *Lymnaea columella*). Others are found so far in only small areas, for example, *Amerianna carinata* and *Indoplanorbis exustus* in Nigeria (Brown, 1983; Kristensen & Ogunnowo, 1987) and *Gyraulus chinensis* in Guinea Bissau (Brown et al., 1998). *Helisoma duryi* was deliberately introduced into Tanzania for trial as a competitor and biological control agent of intermediate hosts for schistosomes, but although it appears in artificial habitats in many parts of Africa, presumably as an escapee from aquaria, it appears unable to establish itself in more natural habitats over any large area. Field trials with another snail considered to be a potential biological control agent, *Marisa cornuarietis,* were carried out in Egypt, Sudan and Tanzania (Brown, 1994: 406); it was concluded that this snail would be unlikely to establish populations in rice fields in the Nile Valley as flooded periods are too short (Haridi & Jobin, 1985). *Biomphalaria glabrata* is an apparently recent, accidental introduction of Egypt, where it is spreading (Yousif et al., 1996), possibly at the expense of *B. alexandrina*. The impact of introduced snails on the indigenous fauna has not been monitored, though laboratory experiments (Appleton & Brackenbury, 1998) indicate that *Physa acuta* is a successful competitor of both *Bulinus tropicus* and *Lymnaea natalensis.*

Snail Control

Snail control in Africa by means of molluscides has been attempted most ambitiously, and at great expense, in Egypt and Sudan. The earlier programmes were area-wide, applying molluscicide to entire water systems. Area-wide treatment did not produce the expected degree of disease control (Gilles et al., 1973; Fenwick, 1987; Webbe & El Hak, 1990), and today the consensus is that mollusciciding should be restricted to small focal sites. This change in thinking, combined with the high cost of mollusciding and efforts to find substances and techniques to achieve selective killing of only target-snails, has considerably reduced the threat to other organisms. Yet while their threat to aquatic ecosystems should not be exaggerated, synthetic molluscicides are undoubtedly not selectively toxic to snails of medical and veterinary importance, and they are known to kill various other invertebrates, amphibians and fish (Appleton, 1985; Appleton & Madsen, 1998). Although rapid recovery of some invertebrates is reported, including unfortunately target snails, it does not necessarily follow that similar resilience would be shown by an isolated population of a snail species adapted to a specialised niche, since there might be no possibility of recolonisation.

Even at focal sites in lakes there are great technical problems in achieving adequate concentrations of molluscicide, because of the large volume of water and the presence of sheltered niches for snails among vegetation and rocks. Efforts to solve such problems in Lake Volta, Ghana, achieved only a short-term reduction in incidence of schistosomiasis (Chu et al., 1981). After intensive mollusciciding in the small crater-lake Barombi Kotto in Cameroon, *Bulinus camerunensis* rapidly reestablished its population and ten years later the prevalence of schistosomiasis was almost as high as before (Moyou et al., 1984).

These experiences should discourage health workers from attempting to control schistosomiasis by applying molluscicide on the open shores of such lakes as Malawi and Tanganyika. However, it might seem attractive to treat small pockets of marshy habitat, especially close to tourist resorts. Unfortunately, it would be difficult to ensure that this would cause no harm to non-target snails living nearby.

In order to make mollusciding unnecessary, biological agents for the control of intermediate hosts of schistosomes have been sought for many years. The various candidate organisms tested include other snails, insect larvae, crustaceans and fish. Often the species have been indigenous to Africa, but some alien organisms have been introduced, as described above. Field trials have been few, and only limited success was achieved. As a general principle, an alien mollusc should not be introduced into Africa, in view of the unpredictable effect it might have on the indigenous fauna.

RELATIONSHIPS BETWEEN CONTROL OF SNAIL-BORNE DISEASE AND CONSERVATION OF BIODIVERSITY

It is perhaps in lakes Malawi and Tanganyika that the endemic freshwater snails of Africa face the greatest potential threat from snail control operations. Schistosomiasis is not generally so much a problem in two other areas with important threatened snail faunas, the forested uplands of West Africa and the Congo Basin. The distribution of *Tomichia* in southern Africa lies almost entirely outside the range of intermediate hosts for schistosomiasis. Of other snail-borne trematode infections, paragonimiasis occurs in an extensive western area inhabited by rare species of prosobranch, but snail control is unlikely to be used against this disease. The only area of fascioliasis infection where snail control has been attempted is Lesotho, where no endemic freshwater mollusc is known.

From these considerations the potential threat to the endemic snail fauna and general biodiversity in African freshwaters from snail control seems no greater, and is perhaps less, than the dangers from pollution and habitat destruction. Providing those working for disease control behave responsibly, there should be no conflict with the interests of conservationists. On the contrary, we would stress that there are mutual interests to unite medical malacologists, health authorities and conservationists. All these specialists can advance their objectives by demanding that greater care be taken in the siting and planning of dams and irrigation schemes, since these not only destroy natural habitat but also can have bad consequences for public health (Hunter et al., 1993). A case in point is the Diama Dam across the lower Senegal River, completed in 1985. Since then, large populations of *Biomphalaria* have appeared in irrigated areas upstream, accompanied by a dramatic rise in incidence of intestinal schistosomiasis, which has reached prevalences among the highest recorded in Africa (Southgate, 1997).

Another area of concern to both health authorities and conservationists must be pollution and degradation of freshwater habitats, for these processes not only endanger threatened aquatic species, but also put at risk the supply and quality of water essential to the health of human communities.

In this way it can be argued that a policy for conserving biodiversity in the fresh waters of Africa favours the objective of controlling snail-borne parasitic disease, and also contributes to the sustainable use of that indispensable natural resource, water.

CONCLUSIONS

Fortunately, only a few species of African freshwater snail are thought to have become recently extinct. But this is no reason for complacency, as there is no up to date information about many of the species that have been reported from a single site or only a few localities. Indeed, about two-thirds of all the species known can be classified as Threatened according to IUCN categories. Threatened species seem most exposed to potential danger from snail control in lakes in eastern Africa. Here, as in the Congo Basin, great care should be taken to avoid damage to endemic snail faunas that are of high importance for conservation. Yet in general the threat to biodiversity from snail control measures appears no more, perhaps less, than the threats from pollution, hydrological engineering and degradation of habitat. High biodiversity is a sign of the ecological health of a freshwater habitat. To preserve high biodiversity serves the interests of medical malacologists and health authorities as well as conservationists, since poorly planned dams and irrigation schemes can cause health problems, while pollution and degradation of habitat endanger water supplies that are essential for the health and prosperity of people in Africa. The diversity of the unique forms of gastropod that have evolved in the lakes of eastern Africa, and the radiations of species in western rivers, attract the interest of people worldwide who appreciate the wonderful variety of life on earth. Medical malacologists have an opportunity to help to ensure that people of future generations can see these species alive, not only as specimens in museums.

RECOMMENDATIONS

In order to avoid unnecessary damage to freshwater biodiversity from snail control programmes, the following code of practice is suggested for medical malacologists, who are the people with direct responsibility for snail control measures.

(1) A medical malacologist who considers the use of molluscicide to be justified, having taken into account possible damage to biodiversity, should restrict the application to the smallest practicable area and minimise the dispersal of chemicals into the wider ecosystem.
(2) It should be the responsibility of medical malacologists working with health authorities to obtain knowledge of the conservation status of the molluscan fauna in their area.
(3) Before commencing a water resource development or molluscididing programme, there should be consultation with national authorities and also non-governmental organisations concerned with conservation of aquatic life.

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